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Volatile Organic Compounds in Indoor Air
A Survey of Various Structures

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16. ABSTRACT

Co-workers collected indoor air samples in their homes in SUMMA polished canisters. Upon receipt in the laboratory, the whole air samples were analyzed for volatile organic compounds (VOCs) using cryogenic sample preconcentration and subsequent capillary column chromatography. Each homeowner was asked to fill out a questionnaire concerning physical, structural and activity-related characteristics that could affect VOC concentrations. Simultaneous flame ionization and electron capture detection yielded quantitative concentration data in a range 0.1 to 10 ppbv for 19 calibration compounds: propane, vinyl chloride, vinylidene chloride, Freon 113, chloroform, 1,2 dichloroethane, methyl chloroform, benzene, carbon tetrachloride, trichloroethylene, cis-1,3-dichloropropene, trans-1,3-dichloropropene, toluene, 1,2 dibromoethane, tetrachloroethylene, chlorobenzene, o-xylene, benzyl chloride and hexachlorobutadiene. Certain other compounds could also be identified and quantified based upon occasional analyses of appropriate standards. These data are presented in three sample groups; summer indoor samples, winter indoor samples, and combined summer and winter outdoor samples. In addition, some probable correlations between residential characteristics and the occurrence of various compounds in indoor air are discussed.

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VOLATILE ORGANIC COMPOUNDS IN INDOOR AIR: A SURVEY OF VARIOUS STRUCTURES

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VOLATILE ORGANIC COMPOUNDS IN INDOOR AIR: A SURVEY OF VARIOUS STRUCTURES

Introduction

In preparation for a more definitive scientific study of the occurrence and sources of volatile organic compounds (VOCs) in residential air, we have conducted a limited survey of homes in the Research Triangle Park area of North Carolina. The objective has been to uncover the more obvious associations between VOC concentrations and factors affecting their presence, with emphasis on winter-summer comparisons. As part of the study, a questionnaire was prepared, as shown in Figure 1. Co-workers were asked to open evacuated metal containers in their homes to obtain whole air samples (no more than two minutes was needed to fill the containers). The containers were sealed and returned to the laboratory for analysis. A total of 15 summer samples and 16 winter samples was analyzed. There were only five homes in which both winter and summer samples were taken. A total of 26 homes was included in the study. Due to the limited sample set, some individual VOCs were observed infrequently and therefore conclusions based upon their association with the characteristics of the sampling location are tentative.

Experimental Approach

Equipment

Samples were collected in spherical 6-L (Demaray Scientific Instruments, Ltd., Pullman, WA) or in rounded, cylindrical, 3-L (Biospherics Research Corp., Hillsboro, OR) stainless-steel canisters with stainless-steel bellows valves (Nupro Co., Willoughby, OH). Internal canister surfaces came electropolished with the SUMMA® process (U.S. Patent 764462) to passivate any active adsorption sites. The storage stability of ppbv-level VOCs in this type of container has been verified for time periods from one week (using our containers[1]), up to periods of one or more years[2,3] as described by others. In this study, sample analyses were always performed within six days after collection.

All analyses were performed using an automated Nutech 320-01 cryogenic sampling instrument (Nutech Corp., Durham, NC) equipped with a Seiscor model VIII six-port valve (Seismograph Service Corp., Tulsa, OK) and a Hewlett-Packard model HP 5888OA, Level 4 gas chromatograph (GC) with an OV-1 50-m X 0.31-mm I.D. capillary column (Hewlett-Packard Corp., Avondale, PA). The column exit is split to allow simultaneous detection with a flame ionization detector (FID) and an electron capture detector (ECD). All phases of sampling from the canisters, sample preconcentration, on-column injection, and analysis were under automatic control using the programming capability of the GC. A detailed description of this system and its automated operation is available.[4] The sample stream was dried with a model MD-125-48(T) Perma-Pure dryer (Perma-Pure Products, Inc., Farmingdale, NJ) to avoid column or trap blockage due to ice formation. Performance and sample integrity data for these dryers are also available.[5,6] Periodically, compound identification was verified on a similar GC system equipped with a quadrupole mass spectrometric detector (HP 5970 MSD, Hewlett-Packard Corp.). These analyses always confirmed identifications that were based only upon retention time and FID/ECD response comparisons.

Experimental Procedures

Canisters were prepared for sampling by heating to 100°C while evacuating to less than 5 Pa (~40 μm Hg). Previous experimentation has shown this procedure to reduce any residual contamination well below minimum detectable levels. Cleaned, evacuated canisters were fitted at the inlet with Teflon particle filters (0.5 μm pore, 47 mm diameter, Millipore Corp.,

Bedford, MA) in Teflon holders (Mace, South El Monte, CA). Filters and holders have been tested to verify that they do not affect VOC sample integrity.

Canisters were issued to a number of co-workers who were asked to open them either in a central location in their home or near the return duct of an operating central air handling system. In addition to filling out the questionnaire (see Figure 1), each person was asked to indicate any special circumstances that may have influenced the sample. Particularly, these included whether or not the heat or air conditioning was on. In some cases, certain samples were later dropped from data compilation due to an unusual occurrence that made the sample non-representative.

Upon receipt in the laboratory, the canister (now at atmospheric pressure) was pressurized further to 3×10^5 Pa (30 psig) with zero-grade nitrogen. For analysis, the pressurized sample was released from the canister through a Tylan FC-260 mass flow controller (Tylan Corp., Carson, CA) and vented past the analytical system inlet at 75 ml/min. The sample was collected in the cryogenic preconcentrator at a rate of 34 ml/min for 14 min to trap a total of 476 ml. Even the 3-L canisters were capable of supplying adequate sample for at least three replicate analyses if needed. Post-processing of data included accounting for the initial dilution and applying the latest calibration parameters.

The system was usually calibrated twice a week for 19 compounds of interest as listed in Table I for a concentration range of 0.1 to 10 ppbv. FID response is linear with concentration well beyond the maxima observed, however, ECD response is subject to detector sensitivity roll-off for some compounds at concentrations greater than ~5 ppbv. We correct for this ECD non-linearity where appropriate. Calibration data consisting of retention times and detector response parameters were kept current in the GC computer system. In addition to the 19 calibration compounds, we have accumulated detection parameters for additional compounds based upon transfer standards from other laboratories. These compounds (also listed in Table I) are generally considered as tentative in quantitation because their response data are based on only a few analyses of standards.

Determination of air quality is not restricted to individual compound speciation. We have also prepared a number of samples where suspected source vapors are injected into canisters and diluted to ppbv levels with zero-grade air. We can then compare detector response patterns from these known samples to samples from homes to help identify possible VOC sources.

Results and Discussion

Observed Compounds and Mean Concentrations

Indoor air data were compiled separately for summer and winter samples. A third data set consisting of six outdoor winter and six outdoor summer samples was compiled for comparison. These outdoor samples were taken at various times and locations during periods of indoor air sampling. The number of times a compound was observed, the mean ppbv concentration of observed samples, and the ppbv range (min, max) are listed in Table II. Only compounds seen three or more times are included. In addition, two "air quality" indicators were devised; the number of FID peaks greater than an arbitrary value of two area counts and the number of ECD peaks greater than an arbitrary value of 10^4 area counts are reported. The FID number is an indication of total volatile hydrocarbons present (with the exception of very light compounds not preconcentrated at –155°C) whereas the ECD number is an indication of the multiply halogenated hydrocarbons.

As shown in Table II, the compounds benzene, toluene, carbon tetrachloride, tetrachloroethylene and Freon 11 were found in every indoor and outdoor sample. Other compounds, o-xylene, chloroform, methyl chloroform, and trichloroethylene, were found in

most indoor samples, while the remaining compounds, propane, vinylidene chloride, and trichlorotrifluoroethane, were only found a few times each.

When detected, trichlorotrifluoroethane was at similar levels both indoors and outdoors. Carbon tetrachloride was found at essentially constant mean levels for all three data sets; however, its concentration exhibited a greater range in the indoor samples. For the remaining compounds in Table II, the indoor mean concentrations often exceeded the outdoor values by a factor of 10 or more. Also, the average numbers of FID and ECD peaks (as defined earlier) were greater for indoor than for outdoor air.

Correlations Between Compounds and Residence Characteristics

Table III lists the apparent correlations between various characteristics of the residences sampled and specific compounds found. Because these data often rely on only a few occurrences per category, they can be easily influenced by a single data point. For a given compound, correlation categories are listed as contrasts, for example -- house *vs.* apartment, gas heat *vs.* electric, etc. The, two column entries give the ppbv means as ratios both for the summer and winter data. Thus, the example entry

| Toluene | Age > 15 years vs. younger | 42.5 vs. 8.7 | 23.2 vs. 8.6 |

indicates that the means for observed toluene concentrations in residences older than 15 years as compared to younger residences are 42.5 ppbv and 8.7 ppbv, respectively, for summer samples and 23.2 ppbv and 8.6 ppbv, respectively, for winter samples. These example data then suggest that toluene is correlated to older residences and that the summer heat elevates indoor concentrations.

From Table III, the more likely correlations and possible explanations are itemized as follows:

1. Propane is associated strongly and almost exclusively with the presence of a natural gas heating system whether or not it is turned on. Propane is a constituent of natural gas used in this area and its presence may indicate a small gas leak. Methane, the main constituent, is not preconcentrated in our system.

2. The three aromatic hydrocarbons, benzene, toluene, and o-xylene, are associated with older structures, garages as part of the structure, indoor volatiles storage (basements or garages), and kerosene heaters. It is likely that the major sources are evaporative emissions from fuels and solvents. The age correlation is probably not relevant in itself since older homes in this area are just more likely to have basements and garages.

3. The compounds vinylidene chloride, trichlorotrifluoroethane, chloroform, and trichloroethylene were more frequently found in apartments than in houses.

4. Methyl chloroform and chloroform showed a moderate association with older residences.

5. Freon 11 was found in every sample. It was moderately associated with residences younger than 5 years with wall-to-wall carpeting. A strong carpeting correlation has been observed in previous tests involving workplace air; however, since the residences tested here all contained at least some wall-to-wall carpeting, the correlation is only observed when other additional floor materials (i.e., hardwood, linoleum) did not reduce the total carpeted areas. Freon II is used as a foaming agent in carpet padding manufacture.

6. The number of FID peaks was correlated with obvious hydrocarbon sources, such as gas heat, volatiles storage, and kerosene heaters. The number of ECD peaks observed, arising from multiply-halogenated organic compounds, did not follow any noticeable pattern.

Traffic or physical location information did not appear to correlate with any compound. Insulation and storm doors and windows were correlated with slightly higher VOC concentrations.

Qualitative Comparisons

Sometimes sources of VOCs in the home are more easily found by GC peak patterns than by individual compound identification. To facilitate such detection, we generated a library of chromatograms of natural gas, gasoline, car exhaust, paint thinner, glue solvent, kerosene fuel, and wood smoke. When these were compared to the more complex chromatograms of indoor air samples, some obvious correlations could sometimes be made. FID traces were much more useful for these comparisons since many more compounds were detected.

Figure 2 shows an example where paint thinner vapors are identified as contaminants in the indoor air. In this, and other cases (e.g., natural gas, gasoline), the patterns are easily recognized.

Questionnaire Evaluation

Data compilation and analysis have illustrated some areas for improvement in the questionnaire (refer to Figure 1). Though the questionnaire was reasonably complete, some questions need to be explicitly asked rather than implied, and in some cases, multiple choice questions need to be reworded.

Rather than rely on the subject to furnish "relevant comments," questions concerning (1) recent cooking activity, (2) what, if any, cooling or heating system was on, and (3) recent hobby or construction activity should be asked. Also, because a chlorinated water supply can outgas certain VOCs, some explicit questions should be added concerning the water source (i.e., well or city) and recent water use activities, such as running a dishwasher, showering, and washing clothes.

The physical location section should be split into three distinct questions to determine (1) the physical setting, i.e., terrain and vegetation, (2) proximity to nearest urban center, and (3) traffic both very near the residence and within $\sim\frac{1}{4}$ mile.

Conclusions

Though this pilot study was limited to a small sample set, single samples per residence, and a single geographical setting, some preliminary conclusions can be drawn. Certain VOCs are regularly found in residential air at concentrations greatly exceeding ambient levels. Indoor storage of paints and gasoline, fossil fuel heat, and attached garages tend to correlate to higher hydrocarbon levels. Overall, summertime VOC levels in the home tend to exceed wintertime levels, possibly due to outgassing of structural materials.

This study has raised questions for further investigation and provided suggestions for a more relevant VOC questionnaire. A number of possible correlations between compounds and residence parameters should be further investigated with many more samples to allow for proper statistical treatment. Qualitative comparisons of specific source chromatograms to sample chromatograms show promise for quickly identifying certain multi-compound

contamination sources. This technique should be further developed by expanding the set of source samples and identifying specific peak patterns by retention times and area ratios.

Time-integrated sampling of several hours duration is also being considered as an alternative to the short duration (< 2 min) sampling. This change would require additional equipment to obtain constant sampling rates, but would provide a sample more representative of VOC-related exposure.

References

1. K. D. Oliver, J. D. Pleil and W. A. McClenny, "Sample integrity of trace level volatile organic compounds in ambient air stored in SUMMA® polished canisters," Submitted to Environ. Sci. Technol., (1985).

2. R. A. Rasmussen and J. E. Lovelock, "The atmospheric lifetime experiment, 2. Calibration," J. Geophys. Res., 88: 8369-8378 (1983).

3. R. A. Rasmussen and M. A. K. Kahlil, "Atmospheric halocarbons: Measurements and analyses of selected trace gases," Proc. NATO ASI on Atmospheric Ozone, 209-231 (1980).

4. W. A. McClenny, J. D. Pleil, M. W. Holdren and R. N. Smith, "Automated cryogenic preconcentration and gas chromatographic determination of volatile organic compounds in air," Anal. Chem. 56: 2947-2951 (1984).

5. M. W. Holdren, S. Rust, R. N. Smith and J. Koetz, "Evaluation of cryogenic trapping as a means for collecting organic compounds in ambient air," U.S. EPA Report No. EPA-600/4-85-002, Research Triangle Park, NC (1985).

6. B. E. Foulger and P. G. Simmonds, "Drier for field use in the determination of trace atmospheric gases," Anal. Chem. 51: 1089-1090 (1971).

TABLE I. LIST OF COMPOUNDS FOR WHICH THE ANALYTICAL SYSTEM PROVIDES IDENTIFICATION AND QUANTITATIVE DATA

Calibration Compounds	Other Recognized Compounds
Propane	Freon 11 (CCl_3F)*
Vinyl chloride	Freon 12 (CCl_2F_2)*
Vinylidene chloride	Freon 13 ($CClF_3$)
1,1,2-Trichloro-1,2,2-trifluoroethane*	Freon 22 ($CHClF_2$)
Chloroform*	1,2-Dichloropropane
1,2-Dichloroethane	Bromoform*
Methyl chloroform*	*o*-,*m*-,*p*-Dichlorobenzene
Benzene	Allyl chloride
Carbon tetrachloride*	1,1,2,2-Tetrachloroethane*
Trichloroethylene*	1,1,2-Trichloroethane
cis-1,3-Dichloropropene	Methylene chloride
trans-1,3-Dichloropropene	*m*-,*p*-Xylene
Toluene	1-Bromo-3-chloropropane
1,2-Dibromoethane*	Methyl chloride
Tetrachloroethylene*	Ethyl benzene
Chlorobenzene	
o-Xylene	
Benzyl chloride	
Hexachloro-1,3-butadiene*	

*Compounds that exhibit strong ECD response in addition to FID response. We quote ECD data for these compounds.

TABLE II. RESULTS FOR DETECTION OF INDIVIDUAL COMPOUNDS; COMPARISON OF INDOOR SUMMER, INDOOR WINTER, AND OUTDOOR SAMPLES

Compounds	Indoor Air						Outdoor Air		
	Summer Data 15 Samples			Winter Data 16 Samples			Summer & Winter 6 Samples of each		
	# Obs.	Mean ppbv	Range ppbv (min, max)	# Obs.	Mean ppbv	Range ppbv (min, max)	# Obs.	Mean ppbv	Range ppbv (min, max)
Propane	6	32.6	(1.0, 149)	3	27.6	(3.8, 68.0)	0	–	– –
Benzene	15	7.6	(0.39, 48)	16	4.8	(0.53, 23.6)	12	0.57	(0.33, 0.77)
Toluene	15	22.2	(2.3, 87)	16	12.2	(0.27, 49.3)	12	1.05	(0.23, 2.18)
o-Xylene	14	2.78	(0.31, 13.4)	13	2.49	(0.32, 4.4)	9	0.45	(0.04, 0.77)
Vinylidene chloride	4	47.3	(1.8, 93.6)	4	7.1	(5.0, 9.6)	0	–	– –
Trichlorotrifluoroethane	3	0.22	(0.19, 0.26)	0	–	– –	8	0.24	(0.11, 0.36)
Chloroform	10	1.89	(0.13, 3.8)	12	2.11	(0.85, 2.5)	0	–	– –
Methyl chloroform	13	1.90	(0.44, 8.9)	15	0.77	(0.32, 1.3)	7	0.26	(0.19, 0.38)
Carbon tetrachloride	15	0.14	(0.09, 0.23)	16	0.14	(0.11, 0.16)	12	0.15	(0.13, 0.16)
Trichloroethylene	10	1.64	(0.29, 2.7)	9	1.88	(0.59, 3.6)	0	–	– –
Tetrachloroethylene	15	0.86	(0.10, 4.6)	16	1.51	(0.11, 11.9)	11	0.18	(0.3, 1.34)
Benzyl chloride	0	–	– –	3	6.23	(4.9, 7.2)	0	–	– –
Freon 11	15	0.62	(0.11, 2.86)	16	0.54	(0.14, 1.65)	12	0.14	(0.08, 0.38)
#FID Peaks > 2	15	50.6	(13, 125)	16	41.8	(12, 123)	12	5.8	(0, 13)
#ECD Peaks > 104	15	7.3	(4, 11)	16	5.9	(4, 9)	12	4.2	(2, 7)

TABLE III. APPARENT CORRELATIONS; PRESENCE AND AMOUNTS OF SPECIFIC COMPOUNDS AS RELATED TO VARIOUS PARAMETERS OF RESIDENTIAL STRUCUTRE OR ACTIVITY

Compound	Correlation Category	Comparison of Mean ppbv Levels when Detected	
		Summer samples	Winter Samples
Propane	Gas heat installed vs. electric	30 vs. 0	40 vs. 4
Benzene	House vs. apartment	8.6 vs. 1.2	5 vs.5
	Age > 15 years vs. younger	17 vs. 1.5	4.6 vs.4.8
	Brick vs. wood frame	11.7 vs. 1.5	3.4 vs.5
	Basement vs. other foundation	24 vs. 1.7	2 vs. 4
	Gas heat installed vs. electric	17 vs. 1.2	3.9 vs. 2.8
	Garage: attached or under vs. not	24 vs. 1.5	8 vs. 2.9
	Storage of volatiles: inside vs. not	13 vs. 1.8	7 vs. 2
	Heat on: woodstove vs. avg.	NA	1.5 vs. 4.8
	gas vs. avg.	NA	4.7 vs. 4.8
	kerosene vs. avg.	NA	16.2 vs. 4/8
	electric vs. avg.	NA	3.2 vs. 4.8
Toluene	House vs. apartment	23.6 vs. 13	12.7 vs. 12.9
	Age > 15 years vs. younger	42.5 vs. 8.7	23.2 vs. 8.6
	Brick vs. wood frame	26.6 vs. 14.9	8 vs. 12.8
	Basement vs. other foundation	65 vs. 12.4	19.8 vs. 11.2
	Gas heat installed vs. electric	34.8 vs. 13.8	9.6 vs. 11.2
	Garage: attached or under vs. not	50 vs. 12	13.3 vs. 11.5
	Storage of volatiles: inside vs. not	36.6 vs. 5.7	19.2 vs. 4.7
	Heat on: woodstove vs. avg.	NA	1.5 vs. 12.2
	gas vs. avg.	NA	11.6 vs. 12.2
	kerosene vs. avg.	NA	15.2 vs. 12.2
	electric vs. avg.	NA	16.5 vs. 12.2

(continued)

TABLE III. (continued)

Compound	Correlation Category	Comparison of Mean ppbv Levels when Detected	
		Summer samples	Winter Samples
o-Xylene	House vs. apartment	3 vs. 1.6	3 vs. 1.5
	Age > 15 years vs. other	4.9 vs. 1.2	2 vs. 2.6
	Brick vs. wood frame	3.6 vs. 1.1	1.5 vs. 2.8
	Basement vs. other found	7 vs. 1	1 vs. 2.4
	Gas heat installed vs. electric	4.8 vs. 1.3	2.8 vs. 1.7
	Garage attached or under vs. not	7.2 vs. 1	4.3 vs. 1.4
	Storage volatiles vs. not	4 vs. 1.1	3.2 vs. 1.3
	Heat on: woodstove vs. avg.	NA	0.7 vs. 2.5
	gas vs. avg.	NA	2.8 vs. 2.5
	kerosene vs. avg.	NA	5.7 vs. 2.5
	electric vs. avg.	NA	1.72.5
Vinylidene chloride	No correlations found, but seems more prevalent in apartments		
Trichlorotrifluoroethane	No correlations found, but seems more prevalent in apartments		NA
Chloroform	Apartment vs. house	2.6 vs.1.7	3.8 vs. 1.7
	Age > 5 years vs. less	1.9 vs. 0	2.7 vs. 1.5
	Brick vs. wood frame	2 vs. 1.6	2.6 vs. 1.5
Methyl chloroform	Age > 15 years vs. less	2.5 vs. 1.3	1 vs. 0.7
	Brick vs. wood frame	2.4 vs. 0.9	0.8 vs. 0.7
	Gas heat installed vs. electric	2.5 vs. 1.4	0.9 vs. 0.6
Carbon tetrachloride	No particular correlations found		
Trichloroethylene	Apartment vs. house	1.8 vs. 1.6	2.8 vs. 1.6
	Volatiles storage inside vs. not	1.7 vs. 1.6	2.6 vs. 1.0
	Heat on: woodstove vs. avg.	NA	1.2 vs. 1.6
	gas vs. avg.	NA	2.4 vs. 1.6
	kerosene vs. avg.	NA	1 vs. 1.6
	electric vs. avg.	NA	2.2 vs. 1.6

(continued)

TABLE III. (continued)

Compound	Correlation Category	Comparison of Mean ppbv Levels when Detected	
		Summer samples	Winter Samples
Tetrachloroethylene	Wall-to-wall carpet vs. other floor coverings	0.9 vs. 0.6	1.5 vs. 0.2
	Volatiles storage inside vs. not	1.2 vs. 0.5	2.5 vs. 0.2
Benzyl chloride	No particular correlation found		
Freon 11	House vs. apartment	NA	
	Age < 5 years vs. older	0.61 vs. 0.51	0.56 vs. 0.24
	Wall-to-wall carpet vs. other floor coverings	0.87 vs. 0.51	0.65 vs. 0.44
# Peaks FID > 2	Gas heat installed vs. electric	0.61 vs. 0.44	0.53 vs. 0.36
	Volatiles storage inside vs. not	66 vs. 41	51 vs. 31
	Heat on: woodstove vs. avg.	57 vs. 43	52 vs. 25
	gas vs. avg.	NA	27 vs. 42
	kerosene vs. avg.	NA	54 vs. 42
	electric vs. avg.	NA	68 vs. 42
# ECD Peaks > 10K	No particular correlations found	NA	33 vs. 42

INDOOR AIR SAMPLE QUESTIONNAIRE

Sample ID: _____

Please answer the following questions.
If multiple choice, circle all applicable responses.
Write any relevant comments on the back.
Remember your sample ID to get your results. Names are not recorded.

1) Date: _____

2) Type of structure: house, duplex, condo, apartment, mobile home, other _____

3) Age of structure: _____ years.

4) Construction material: wood, frame, brick, cinder block, log, concrete, other _____

5) Floors: linoleum, stone, tile, wall-to-wall carpet, throw rugs, other _____

6) Foundation: concrete slab, footings on earth, crawlspace, basement, other _____

7) Insulation: ceilings, floors, storm windows *(or double pane)*, storm doors *(or insulated doors)*, other _____

8) Heating: forced air, radiant, electric, heat pump, gas, oil, wood stove, kerosene space heater, coal, other _____

9) Air conditioning: none, central *(regular)*, central heat pump, window unit(s), other _____

10) Cooking: electric, gas, other _____

11) Garage: none, under house, attached, separate.

12) Storage *(for paints, gasoline, etc.)*: none, outbuilding, under house, inside storeroom, other _____

13) Smoking in home: none, rare, light, moderate, heavy.

14) Physical location: rural, suburban, urban, valley, flat area, hill, heavily wooded, lightly wooded, open, near busy road, near airport, near industry, near train tracks, other _____

15) Termite/pest treatment: How often, what type, what chemicals? _____

16) Relevant hobby materials: furniture refinishing solvents, model glues, artist's paints and sprays, etc.: _____

Figure 1. Sample questionnaire.

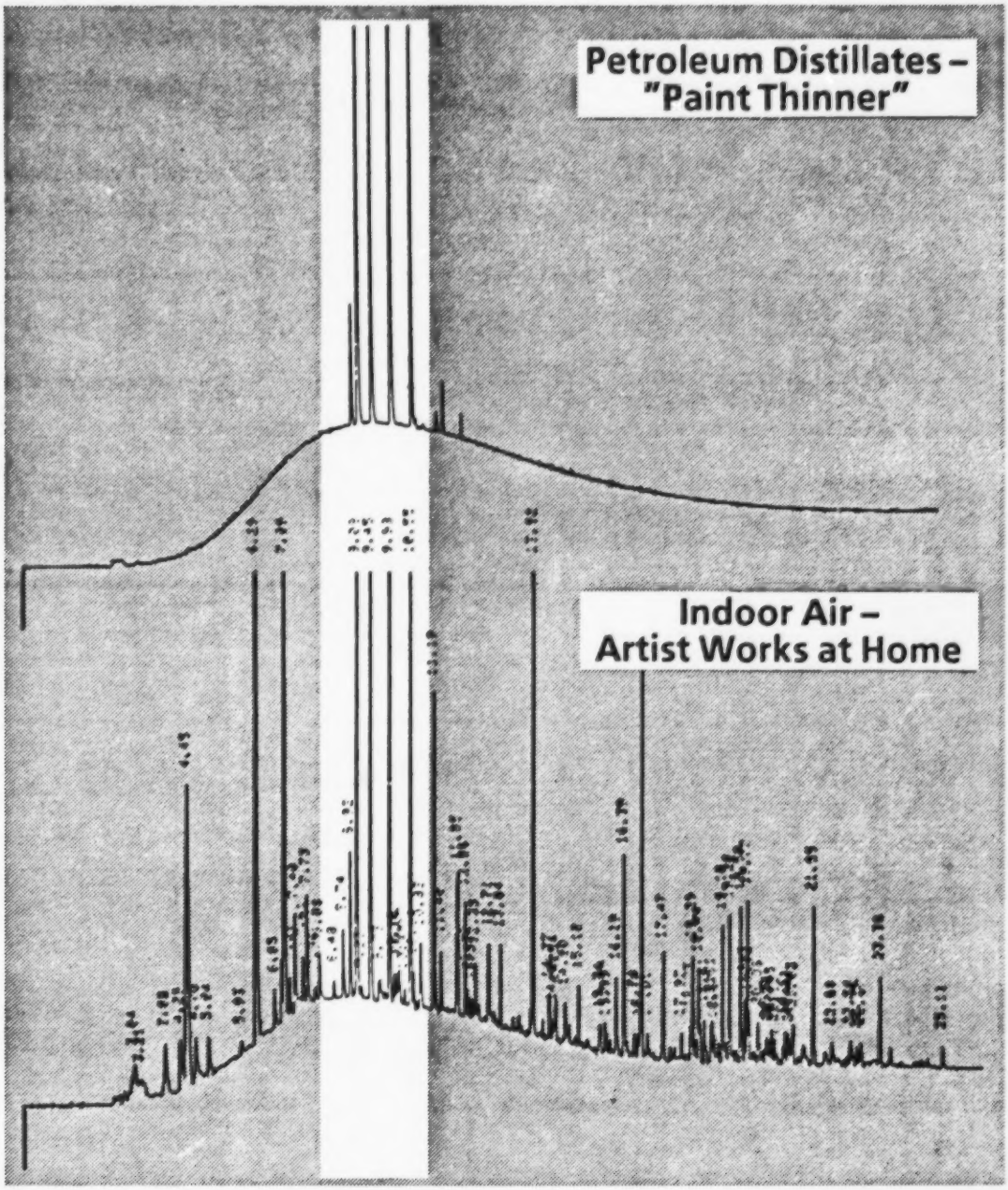

Figure 2. Comparison of FID traces where a source of VOCs in a particular air sample is identified by its peak pattern.